# Linux containers and the Docker environment

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# Introduction

# Monoliths vs micro-services

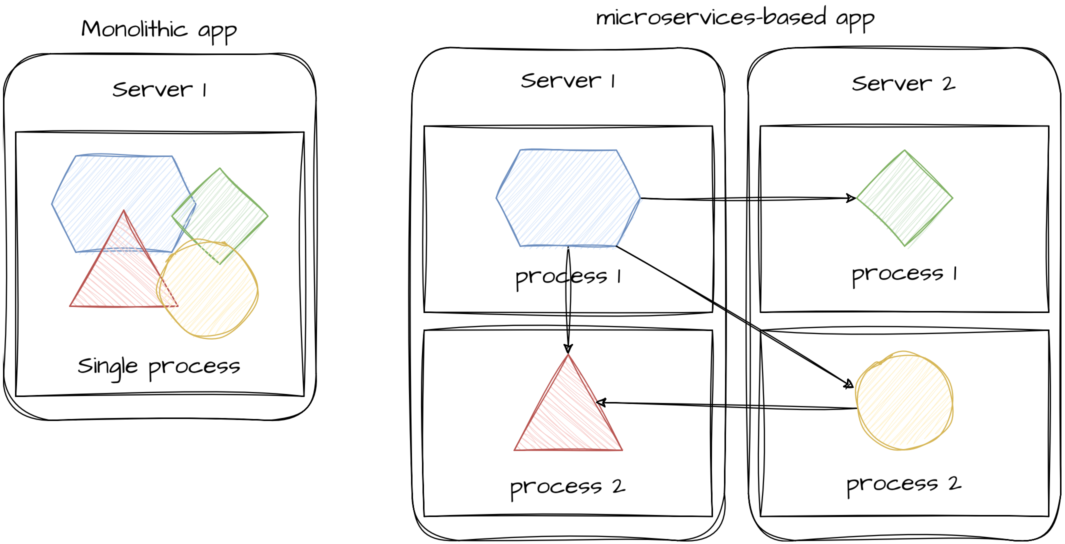
Applications designed as big monoliths

- slow release cycles
- updated infrequently
- lack of flexibility

## Micro-services architectures

- smaller, independently running components
- decoupled from each other
- short and independent release cycles
  - development
  - deployment
  - update
  - scale

# Monoliths vs micro-services



# Problems of micro-services architectures

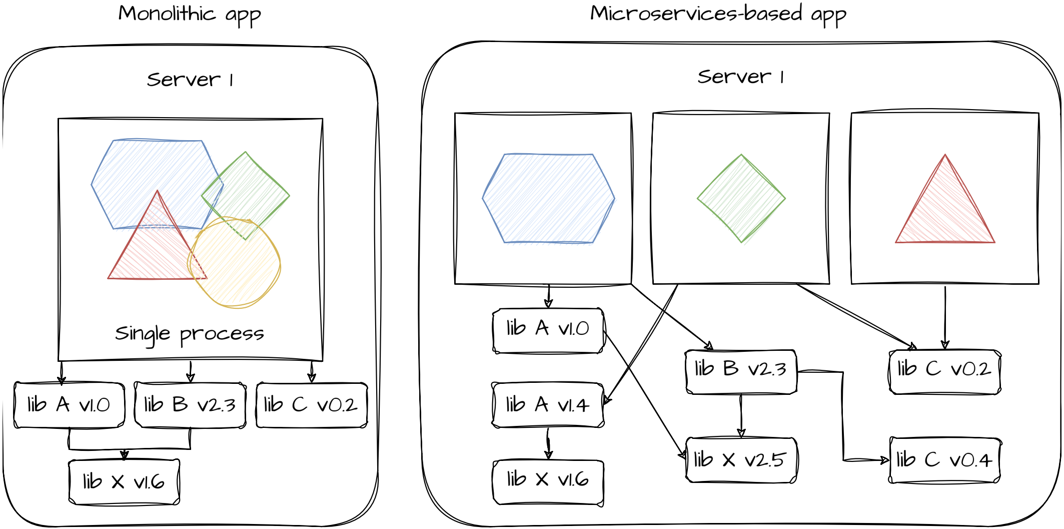
With bigger numbers of micro-services and increasingly complex data centers to deploy them

- difficult to correctly configure and deploy the overall system
- difficult to manage the lifecycle of microservices
- difficult to keep the overall system running

## Need for automation and orchestration

- automatic configuration and deployment (solved with containers and Docker)
- automatic scheduling of micro-services on servers
- automatic supervision and fault-tolerance

# Configuration issue example



# Why not using VMs?

To solve this issue we could

- start as many VM as the number of services
- automate their configuration and the service deployment with Ansible or Bash

## Advantages

- strong isolation
- portability
- better usage of the resources of a machine with co-hosted VMs

## Disadvantages

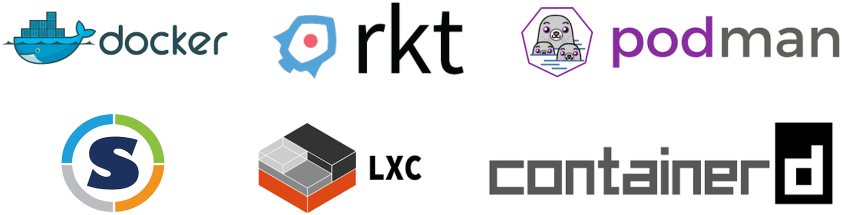
- provision and configure each VM
- data duplication (libraries, kernel)
- performance cost

# Containers

A container is a light virtualization technique

## Container technologies

- Application containers: Docker, podman, rkt, contarinerd
- OS container: LXC Linux
- and others like Singularity for safe HPC containers



# What is a container?

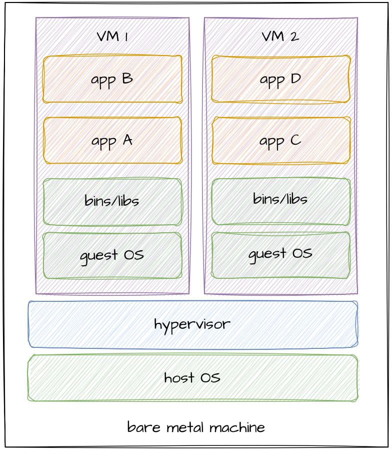
# A bit about Linux kernel

The kernel is the core of the operating system (DEVOS course)

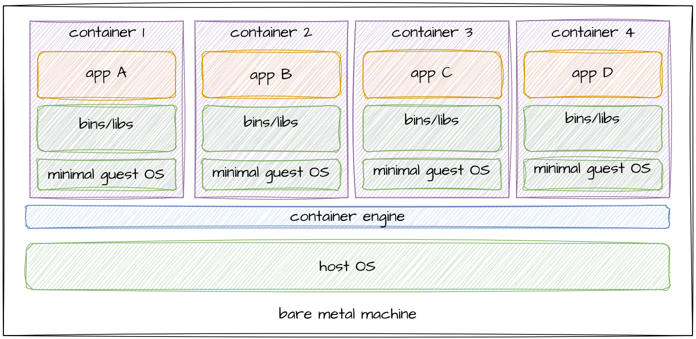
- it is the portion of the OS that is always loaded in memory
- it controls all hardware resources (e.g., I/O, memory, cryptography, CPU) via drivers
- it arbitrates conflicts and concurrency between processes
- it optimizes the utilization of resources (e.g., cache, memory, CPU, file systems, network)

The kernel is one of the first programs loaded on startup

# Coarse-grain comparison between VMs and containers



VMs with hypervisor Type1



Containers

# Containers

## Advantages of containers

- isolation (*)
- portability (*)
- limitations of duplicated resources
- limited impact on performances
- fast startup

The model is different and the way applications are deployed is different!

# What is under the hood?

# A bit more about Linux

In Linux/Unix everything is a file: a file, a directory, a device etc.

### The file system

- hierarchical organization of files
- `/` is root of the file system
- `/sys` contains system files
- `/etc` contains config files and scripts
- `/media` contains hard drives partitions, devices etc.
- etc.

A container is also a set of files!

# Images

A container image is an archive of files containing

- a root file system
- libraries, packages etc. (i.e., dependencies)
- the application or service to run

The image contains the required environment to run the application or the service on top of the host kernel.

This environment is portable from one host to another if a compatible kernel is present (WSL on Windows!)

## Registry of images

- DockerHub *`https://hub.docker.com/`*
- your own registry can be deployed

# Alpine example

The docker image of Linux Alpine is often used by containers

- it is a very light Linux distribution
- https://hub.docker.com/_/alpine

*pull an alpine Docker image*

```
> docker pull alpine
```

*run a container by using the alpine image and start an interactive sh prompt in it*

```
> docker run -it alpine /bin/sh
```

*print the file system of the container*

```
in alpine> ls -al
```

*check there is not any kernel*

```
in alpine> ls /boot
```

# From an image to a container

As seen before an image is an archive of a file system, creating a container consists in

- giving a limited amount of resources to the container
- creating an isolated environment to the container process
- assigning the root file system of the image to the root file system "/" of the container

**`cgroups`**

Linux Control Groups (cgroups) limit the amount of resources a process can consume (CPU, memory, network bandwidth, and so on)

**`namespaces`**

Linux Namespaces make sure each process sees its own personal view of the system (files, processes, network interfaces, hostname, and so on)

**`chroot, pivot_root`**

Change the root filesystem of a process

# Docker

# Overview of Docker

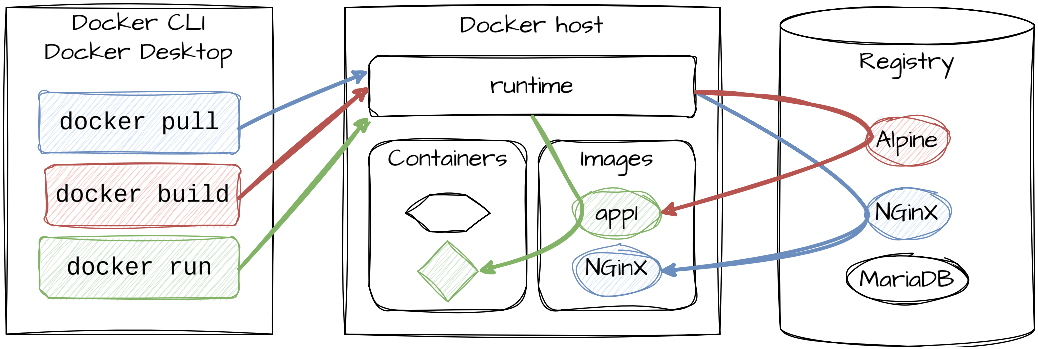
The different pieces involved in the process

- CLI (command line interface)
- Docker runtime
- images and registry
- containers

## Docker runtime

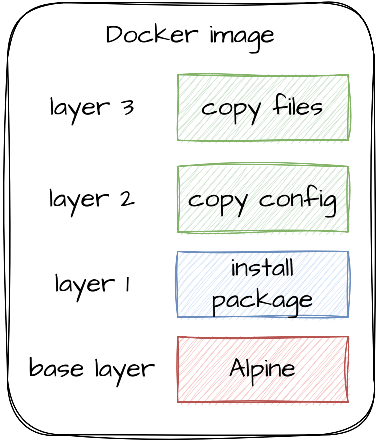
- Start and stop containers
- Manage images
- Manage networks
- Manage volumes
- etc.

# Overview of Docker



# Structure of Docker images

A Docker image is built by assembling different layers



Storage optimization

- layers are shared by different images to optimize storage
- to do that each layer is identified by a hash function according to its content

# Writing in a container?

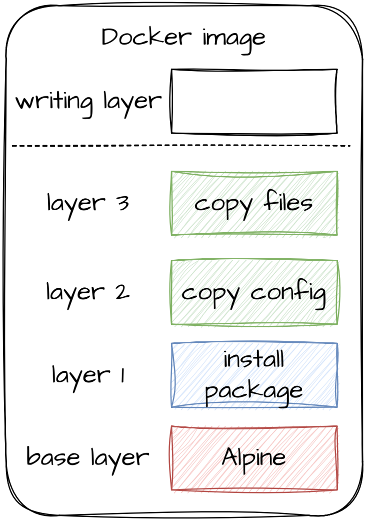
A Docker image is immutable!

At runtime, a virtual layer is created on top of the image

- it is possible to write in this layer
- this layer is not shared with other containers
- the layer is destroyed with the container

**Volumes**

If data has to be persistently stored and shared between containers, a volume has to be used



# Docker CLI

Nothing better than a tutorial to discover the CLI!

# Create an image with a Dockerfile

# Dockerfile principles

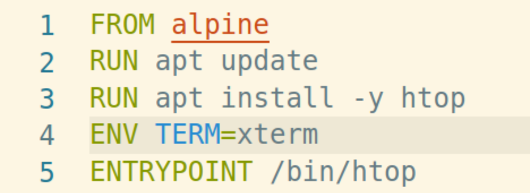
A Dockerfile contains a set of commands to build a Docker image

- avoid building images manually
- offers a way for Docker to build layers and avoid useless commands
- a Dockerfile is close to a bash (or a set of Ansible tasks) with instructions to apply

# Dockerfile through an example

The full documentation is at *https://docs.docker.com/engine/reference/builder/*

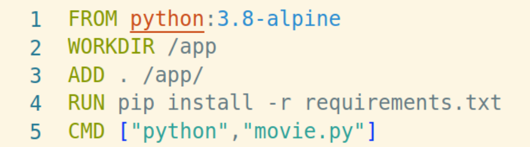
- *FROM* to indicate the base image used to build our image
- *RUN* to execute a command on top of the base image
- *ENV* to declare some environment variables
- *ENTRYPOINT* the command to execute when starting the container



```
FROM alpine
RUN apt update
RUN apt install -y htop
ENV TERM=xterm
ENTRYPOINT /bin/htop
```

# Another example

- *FROM* with an image version
- *WORKDIR* to indicate the working directory when starting the container
- *ADD* to add some files from the local machine to the container image
- *CMD* the command to execute when starting the container



```
FROM python:3.8-alpine
WORKDIR /app
ADD . /app/
RUN pip install -r requirements.txt
CMD ["python","movie.py"]
```

Reference documentation

What are the differences between ADD and COPY? What are the differences between ENTRYPOINT and CMD?

# Build an image with a Dockerfile

```
docker build [OPTIONS] PATH
> docker build . -t "monapp:latest"
```

- `docker build` is the command to build a docker image
- `.` is the path to find the Dockerfile
- `-t` is an option to give a name to the image
- by default the Dockerfile is `PATH/Dockerfile`, you can give another name and use the `-f` option

# Practical session

It is time write a Dockerfile

# Volumes

# Volumes

Two types of volumes

### Host volumes

```
> docker run -v src-dir:dest-dir containe_id
> docker volume ls
```

### Named volumes

```
> docker volume create nom_volume
> docker run -v nom_volume:dest-dir containe_id
> docker volume ls
```

The `VOLUME [/app/logs]` instruction in a Dockerfile only creates the mounting point in the container. It works without it, but it is a good practice to identify easily the need for a volume.

# Practical session

It is time write a Dockerfile with a volume

# A few good practices

# Think about the layers

In the oldest versions of Docker, any line in the Dockerfile created a layer

- too many intermediate layers can be costly costly
- not enough layers can increase the building time
- not enough layers can make impossible storage optimizations
- nowadays only ***RUN***, ***COPY*** and ***ADD*** create new layers

**Good practice 1**

Think about your layers when you use ***RUN***, ***COPY*** and ***ADD*** instructions in your Dockerfile

# Reduce image size

**Good practice 2**

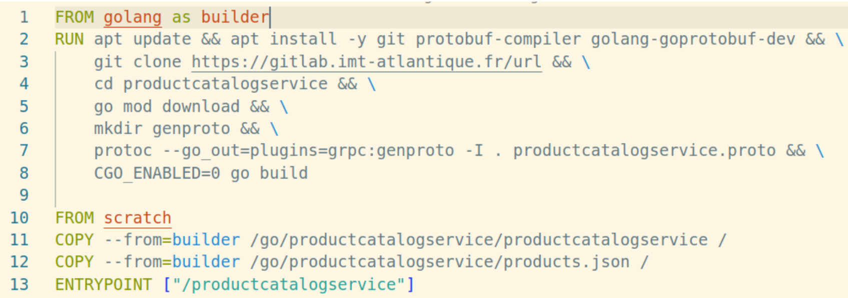
Only install the required dependencies in your Dockerfile

- if using *`apt`* to install packages use *`--no-install-recommends`*
- if possible delete intermediate files not required when applying ***RUN***

# Multi-stage build

## Good practice 3 - do multi stage build

- reduces the size of images by removing compilation dependencies in the final image
- the final image contains only the dependencies required to run the service
- a base image well adapted for executable files only is `scratch` or `alpine`



```
FROM golang as builder
RUN apt update && apt install -y git protobuf-compiler golang-goprotobuf-dev && \
    git clone https://gitlab.imt-atlantique.fr/url && \
    cd productcatalogservice && \
    go mod download && \
    mkdir genproto && \
    protoc --go_out=plugins=grpc:genproto -I . productcatalogservice.proto && \
    CGO_ENABLED=0 go build

FROM scratch
COPY --from=builder /go/productcatalogservice/productcatalogservice /
COPY --from=builder /go/productcatalogservice/products.json /
ENTRYPOINT ["/productcatalogservice"]
```

# Security

Anyone can push a Docker image on Docker Hub!

## Good practice 4 - security

- always prefer official Docker images
- verify that the Docker image is regularly updated
- be sure that the image contains what you think (what are the different layers?)
  - `> docker history image_name`
  - tools like `dive`
- make sure to update the images you are using!

# Additional good practices

- Exposing ports in Dockerfiles
  - *`EXPOSE 80`*
  - *`EXPOSE 53/udp`*
- Adding information with labels
  - *`LABEL maintainer="helene.coullon@imt-atlantique.fr"`*
- Add environment variables
  - *`ENV ADMIN_USER="mark"`*
  - *`docker run -e ADMIN_USER="john"`*
- Add volumes
  - *`VOLUME /myapp/data`*

# Practical session

It is time write a multi-stage Dockerfile

# Deploying a software stack with Docker Compose

# Automating the deployement of containerized applications

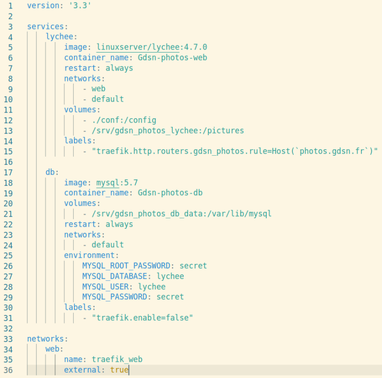
docker
Compose

- easily deploys a containerized software stack
- define your deployment with a single YAML file (containers, volumes, networks, etc.)
- deployment files easy to share, version control, etc.

# Structure of `compose.yaml`

## Full specification

- *`services`*
  - name of the service
    - Docker *`image`* or *`build`* path to the Dockerfile
    - *`ports`* exposed by the service
    - *`networks`* used by the service
    - *`volumes`* used by the service
    - *`environment`* variables used by the service with a value
    - *`depends_on`* another service
- *`volumes`*
- *`networks`*



```yaml
version: '3.3'

services:
  lychee:
    image: linuxserver/lychee:4.7.0
    container_name: Gdsn-photos-web
    restart: always
    networks:
      - web
      - default
    volumes:
      - ./conf:/config
      - /srv/gdsn_photos_lychee:/pictures
    labels:
      - "traefik.http.routers.gdsn_photos.rule=Host(`photos.gdsn.fr`)"

  db:
    image: mysql:5.7
    container_name: Gdsn-photos-db
    volumes:
      - /srv/gdsn_photos_db_data:/var/lib/mysql
    restart: always
    networks:
      - default
    environment:
      MYSQL_ROOT_PASSWORD: secret
      MYSQL_DATABASE: lychee
      MYSQL_USER: lychee
      MYSQL_PASSWORD: secret
    labels:
      - "traefik.enable=false"

networks:
  web:
    name: traefik_web
    external: true
```

It is very important to understand that *`Docker compose`* creates a DNS so that containers can call each other without knowing their IP addresses!

# CLI

Full CLI documentation

A few important commands

- *`build`* to build and rebuild services
- *`up`* to create and start services, networks, etc.
- *`stop`* to stop containers, networks, etc.
- *`down`* to stop and remove containers, networks, etc.

# Try to Compose

It is time to try Docker Compose!

You can also explore samples at this link